AZIMUTH SYSTEMS UK

Airborne Remote Sensing Geocorrection package

AZGCORR

User's manual

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1 Introduction to Azimuth Systems' airborne remote sensing geocorrection program AZGCORR

This program has been developed and refined over a period of years and is the result of the author's experience with airborne remote sensing since the 1980s. The basic method used in **azgcorr** was first tested on images from an ATM scanner in 1989 using "hand adjusted" navigation!

Airborne Remote Sensing has become more common in recent years even with the competition from high resolution satellites. The airbone sensor will of course always have its place as a geophysical instrument because for reasons of resolution, spectral coverage, fly at any time etc.

The contemporary emphasis for geographic data is on computer based "location services", typically using GPS positioning; so the ability to position an aircraft acquired image on a standard map is now of great importance.

Nevertheless it is important to distinguish between the requirements for scientific use and consummer cosmetic uses. An aircraft or satellite image can always be squashed to match a diagramatic map for illustrative purposes. To be able to say that any pixels in a processed image has an error in positioning from it's defined image location of x cm, where x is small, is a totally different problem. This requires both the optimum choice of appropriate navigation equipment and a series a predifined navigation and image "correction" steps prior to the generation of a final corrected image accurately overlaying the desired map**.** If any of these steps are less than optimum x cm will get bigger and irregular; with more error the image may only fit the map erratically.

So the bottom line to achieve user contentment is ultimate accuracy ECEF navigation, followed by painstaking post processing, perhaps scientific massaging to obtain derived data and then careful geocorrection.

azgcorr, therefore, performs the final step in the production of map fitting remote sensing images. As described below, it contains many options for selecting mapping details and image definition and interpolation. This allows it to cater for many types of scanner data and output images on all the main survey grade map projections.

azgcorr, and support utilities, are currently available for Solaris and x86 Linux. Supported scanners are: ATM, CASI; processing of Specim and Hymap have also been performed.

1.1 Future developments

Further developments under way and available during 2003:

a) finalise Linux version
b) generalise scanner support to allow complete user definition
c) change internal files from HDF4 to HDF5 or EOS-HDF5
d) provide access to pixel view vectors for file output or use in level 2 algorithms
e) allow integrated user generation of level 2 products.
f) provide multiple swath support to combine several flight lines
g) provide an interpolation proceedure to correct all bands on a file in one pass

If users wish to make suggestions or have input into future developments they should contact Bill Mockridge at Azimuth Systems (UK): billm@globalnet.co.uk

1.2 Trademarks

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2 Summary of azgcorr functionality

azgcorr combines multi-spectral scanner image data and post processed navigation and produces a map projection referenced rectilinear output image corrected for aircraft position, attitude and ground surface separation computed from aircraft spheroid height, digital elevation data and geoid-spheroid separation estimates.

Special processing is available for non image data (eg: CASI spectral and ILS); corrected pixel coordinates are saved to allow positioning of pixels either on a map or scene image.

Navigation and image data input to **azgcorr** must have been processed, or imported to an internal HDF file, using the correct programs in the Azimuth Systems package to ensure that all data items are present and as expected. The one exception is Level 2 data, the basis of which is image data extracted from a Level 1B file with **azexhdf ;** massaged by a user program and input to **azgcorr** still in BIL or BSEQ format along with its originating Level 1B HDF file.

Navigation data on the internal HDF files is always geodetic (latitude, longitude, spheroid height, pitch, roll, heading) and typically in GPS (WGS84) datum. The conversion to a local datum and map projection, with or without DEM correction is performed just prior to image correction; this allows for maximum flexibility. It is important to note that all appropriate data items (DEM, etc) must be on the same datum and projection. This is discussed below.

Level 1B processing has two main functions: for the raw image data, instrument calibration and corrections have to be applied and the data converted to units of radience; this allows data from different instrumenst to be compared and used for combined calculations.

Navigation data for Level 1B has to be acquired from suitable instruments or processed to achieve ECEF coordinates. GPS data, both position and attitude, as obtained from a GPS receiver is inherently ECEF. INS and combined INS/GPS needs post processing to allow for INS drift, local gravity analmalies, conversion from sensor frame to vehicule frame, etc. In all cases, for the highest accuracy, GPS position needs correction against a fixed base station, ie using techniques of Differential or Kinematic processing.

Inputs to **azgcorr** are run time parameters from the command line, Level 1B HDF, Level 2 HDF or a combined Level 1B HDF and related BIL/BSEQ image file. Outputs are a brief run listing and a Level 3 file. Details the scanner optics are obtained from the command line or HDF file defaults.

"Levels" refer to the NASA definition of satellite or airborne image processed status. The basic definition of these are:

Level 0	raw instrument acquired data, no corrections
Level 1A	radimetric corrections applied
Level 1B	as 1A but with synchronised per scan geo-location data included
Level 2	products derived from Level 1data
Level 3A	Level 1 data geo-corrected
Level 3B	as 3A but with ground control used for precise location

Level 3A processing corrects the image data and interpolates an output image on a regular grid in a recognised map projection coordinate space aligned at a fixed spheroid height, usually zero. It may only approximately match a map in that projection as a map is, in essense, a 2D representation of the surface of the geoid plus the topography. Level 3B processing uses digital elevation model (DEM) data as well as other calibration values (groudn control points GCPs) to achieve precise location that will be optimum for the navigation, DEMs and control.

3 Keywords

Daedalus ATM, geocorrection, geometric correction, geolocation, geocoding, airborne remote sensing, parametric geocoding.

3: Geo-Correction Concepts

3.1 Goals for correction

Stated simply the purpose of the program is to produce an output image which overlays an existing map. The rotating mirror (ATM) or pushbroom (CASI, Hymap) or other scanners have positions calculated for every pixel and then the image is interpolated to a rectilinear grid, which may be projected to a plane relative to the aircraft or related to existing topographic data.

In **azgcorr** it is important to note that this ground referencing is only achieved by using observed scanner (aircraft) position and attitude and referencing scan positioning to elevation (DEMs) information. Ground control points are ONLY used for 'calibrating' DEMs and geoid-spheroid separation data.

In all the following discussion it should be noted that the navigation attitude used HAS to be that attitude experienced by the scan head. If a gps attitude unit is used or a INS/AHRS/IMU that is NOT mounted on the scan head AND the scan head has shock mounts or a stabilised platform then the measured attitude WILL NOT be that of the scan head and azgcorr WILL NOT produce optimum results.

3.2 Navigation - relation to Datums and Spheroids

All navigation on the earth's surface is referenced to a set of axes and a model which describes the static and dynamic geometry of the earth and navigation platform; this is a geodetic datum. For the sake of this discussion we can ignore all parameters except earth geometry and time. For brevity a datum is given a name or even a mnemonic; throughout the world there are several hundred different datums. Current GPS datum is called WGS84 (World Geodetic System agreed in 1984).

To make position observation and calculations tractable the shape of the earth is represented by the nearest simple geometric figure consistent with the desired accuracy. For survey use sufficient accuracy is obtained with a the earth represented by an ellipse rotated about the earth's north south (spin) axis. This 3D figure is called a spheroid (or ellipsoid by some texts).

Of course this simplified figure only approximates the actual earth surface, the geoid, at any point. To relate the two figures a local origin is chosen with measured lateral position and assigned vertical position (height). All heights for a locality are then relative to this reference point. In UK the point is at Newlyn, Cornwall and the height zero is related to mean sea-level. A locality height (topographic) map in grid form is also known as a digital elevation model.

It is important to note that before the days of GPS heights and positions on maps were obtained separately. Heights were by bubble or optical levelling and thus relate to the local gravity normal. Positions were obtained by angular triangulation or optical or microwave trilateration. Both sets of observations have varying errors which are minimised (not removed) by network adjustment. A network of observed points, both position and height can then be 'filled-in' on the ground with more levelling or other techniques or used to scale a series of stereographic aerial photographs from which height and position details can be measured using a stereogrammetric plotter. In general height are an order of magnitude less accurate than positions.

On the other hand, GPS surveying observes both position and height simultaneously, in fact the observation is the 3D axis position of the observation site relative to the centre of the satellite orbit (earth centre). With appropriate equipment and techniques it is possible to make this 3D observation to a few millimetres. More importantly each GPS site is essentially independent from other observations, errors being related mainly to satellite constellation geometry. This allows static site and vehicle positions to be independently observed but retain a very high degree of relative accuracy.

As can be expected there is a problem relating positions obtained from GPS observations and those from traditional geodetic surveying. There is no simple transformation to solve this to any degree of accuracy beyond a few metres; at best a fudge is possible (like the recommended OS procedure for GPS to National Grid). For purely economic reasons the correct solution for a whole country will never be performed, ie. reobserve all original ground points by GPS and recompile all maps.

The relationship between a simple spheroid and its geoid is obtained by a combination of satellite orbit observation, satellite height above sea level measurement and details of the earths local observed gravity. Merging and adjusting this lot using spherical harmonics produces a geoid-spheroid separation map for the spheroid in question. The appropriate sum of the spheroid height, geoid-spheroid separation value and the geoid (DEM) height allows the height of, for example an aircraft, above a DEM to be obtained only using GPS observations to 5 metres or so.

The highest accuracy can only be achieved by GPS ground control points used to calibrate stereo photographs from which new DEMs are obtained. Or by means of the latest laser topographic scanners positioned by GPS (LIDAR).

To summarise for our use of GPS for remote sensing aircraft surveying:

a) surveying and platform positioning is by GPS which gives an observation a 3D position
b) relating dynamic and static observations using GPS is easy to a few tens of centimetres.
c) relating these observations to existing maps requires various adjustments, the first of which is the transformation of the aircraft position on the GPS datum to the local mapping datum; moderate accuracy (few metres) is done using an observed data fudge.
d) more accuracy requires field GPS observation of control points

The default method used in **azgcorr**, to transform from GPS satellite datum (WGS84) to UK National Grid, uses the Ordinance Survey recommended 'National Grid/ETRF89 Transformation Parameters 2/1995 ver 1.2 claimed to be accurate to the 2 metre level.

A second method available from azgcorr version 4.4.0 Jan 2003 uses the release of the OS correction grids and interpolation methods, OSTN97 and OSGM91 provided as option UK99 described in the OS User Guide v1 2/1999. For use in azgcorr this involves a large (5Mbyte), external correction file so it is not set as the default, UK95 covering UK only will remain the default if no other method is selected.

An additional correction grid using OS details in OSTN02 and OSGM02 will be available shortly.

3.3 Map projections

The default procedure for UK outlined above does a one step conversion from WGS lat/long/height to UK national Grid map projection coordinates. The more usual method of transformation does this in two steps allowing more flexibility.

First the GPS position (latitude, longitude and spheroid height) on satellite datum (WGS84) is transformed to a local datum (lat, long, height). Then the geographic (spheroidal) coordinates are transformed to a suitable rectilinear coordinate set using a map projection. Representing points on a spheroid by points on a flat surface, is at best, a compromise. For survey use only a few map projections have the required characteristics of accuracy and scale and direction representation, these are:

a) Transverse Mercator (eg: UTM, UK National Grid etc)
b) Lambert Conical Orthomorphic
c) Universal Polar Stereographic (above 80 degs north or south)
d) other, local, specially designed ones, eg: Dutch, New Zealand

Other projections included are: Mercator, Oblique Mercator and Rectified Skew Mercator.

Each of these projections has a set of defining parameters usually agreed on a national scale. **azgcorr** allows the selection of these projections and parameters; details are described below.

3.4 Digital Elevation data

From the above discussions on datums and map projections it should be clear that elevation data is a measure of heights above some datum on a given spheroid, and without transformation or other massaging can only be used in the context of this spheroid. If the data is also positioned in map projection grid coordinates it is even more closely linked. Consequently care must be taken that selected datum shifts, map projection and DEM data are all self consistent.

Elevation data may be input to the program as **azgcorr** internal format grids (see below), NTF contour or grid files or a flat file. NTF files must comply with the appropriate OS format description for layout and content. **azgcorr** saves or creates a grid from these files, to cover the image area requiring correction. Previously gridded data may not be altered in grid spacing. NTF contour files are converted internally using a user requested grid interval to form the required grid. The requested grid interval must be chosen to be equal to or greater than the output pixel spacing. If too small an interval is used the program run time will increase considerably, the program may run out of memory and no improvement in image correction will be achieved; two times the pixel spacing is more than adequate.

DEMs created from LIDAR observations should be processed to regular grids where the x,y coordiantes are the centres of each grid node. As discussed previously the x,y coordinates have to transformed through the same method as the scanner image data. So if UK99 is used for scanner navigation conversion it must be used in post processing the LIDAR navigation. It should also be noted that problems may occur due to misalignement of the LIDAR and scanner "grids" due to different methods used in calibrating the "view vectors" of each instrument.

In the case where the DEM does not completely cover the image grid the missing parts are filled with default or user supplied fill values before the geoid-spheroid correction is made (if required). In the case of completely offshore sites where geoid-spheroid correction is required provide any grid file, the program will create a zero filled grid and apply the correction; ignore the 'no data' message.

3.5 Time

Time only becomes important when the Level 2 options to calculate pixel view and solar illumination angles are used. Except for these solar calculations for which UTC is required, GPS time of day is used throughout for identifying and merging data. Full details of time will be available with the integrated release of level 2 processing in **azgcorr**.

3.6 Image Interpolation

In the current release three image interpolation options are provided: a) bi-cubic, b) bi-linear and c) nearest neighbour. The first two methods will produce pixel values not in the input image, method c) will not generate extra values and must be used for classified images. In all cases image data is only used if it has DN values between the upper and lower limits stored in SCimover and SCimunder respectively.

User control is also provided for defining the size of gaps that will be interpolated (or filled - nearest neighbour) and the minimum number of pixels considered to be a good 'run'. Both these parameters have limited importance as they only affect the edge of images where the pixel distortion makes the data of little value and generally can be left to default. Care must be taken when a small pixel size is used together with large aircraft motion; in this case the gap parameter may need to be increased to 6, 8 or even 10 to avoid gaps at the image edge.

The nature of the sampling process in both line scan (ATM) and CCD (CASI) scanners results in the DN value obtained for a pixel being a measure of the reflection source by up to two pixels from the centre of a given pixel and controlled by the pixel response function (sort of Gaussian). When interpolating observed scan data to get a rectilinear output no interpolation method is any more 'accurate' than another; just different and all only an approximation to the value that would be obtained if the output pixel was measured directly.

With this in mind, it is suggested that any 'scientific' operation eg. atmospheric correction, is performed on the Level 1 data and geometric correction applied to this Level 2 product. Any 'none

scientific' operation eg classification, is performed on the interpolated geometric corrected image where pixels are in their correct geometric relation with each other.

3.7 CASI and other CCD scanner corrections

Data from this type of scanner may require some extra processing options to cater for the three possible data components recorded in the different operating modes of the instrument: image data, spectral data and ILS.

Briefly the data types consist of:

rec. mode	item	content
SPATIAL:	image:	several bands of continuous pixels
	ILS:	same number of bands of single pixels
SPECTRAL	image:	many bands of spaced out pixels
	SRC	single band continuous pixel image for scene positioning
	ILS:	same number of bands as image for single pixel
ENHANCED SPECTRAL	image:	many bands of continuous pixels but of restricted image width
	SRC	single band continuous pixel image for scene positioning
	ILS:	same number of bands as image for single pixel

Using the appropriate options AZGCORR processes these items as follows:

spatial image, spectral SRC, enhanced spectral SRC and enhanced spectral image: handled as ATM ie continuous image, all three methods of interpolation may be used and a rectilinear interpolated image results.

spectral image, enhanced spectral image and ILS: geometrically corrected grid coordinates are calculated for each pixel and saved on the HDF file to allow positioning over the SRC image. Note that the data items will also be copied to the level 3 file. Coordinates are saved in vectors CAimgxy for image pixels and CAilsxy for the ILS pixel. Note that ONLY selected lines and bands are tranferred to the level 3 file.

spectral image: a special option (-cspi) allows spectral data to be processed as though it was a continuous (touching pixels), space between pixels is filled by the selected interpolation method.

Note that interpolation option has no affect on the pixel coordinates calculated for none image items.

3.8 Viewing the results

Interpolated image items can be converted to BIL or BSEQ files by the **azexhdf** utility and input into any standard image processing package. Coordinates output as listing during the **azgcorr** run can be used to relate the images to maps. Using the GeoTIFF output option in **azexhdf** produces a file containing image data and its registration coordinates; this format is compatible with ERDAS and other image processing packages.

CASI none image items: spectral, enhanced spectral and ILS can be obtained on BIL or BSEQ format files and their related coordinates on separate files for use in user programs.

4: Using azgcorr

4.1Introduction

As supplied **azgcorr** is a unix command line program and is used as any other unix utility. The program is controlled by a selection of command line parameters, expects certain input files and generates program execution message output along with an output image data file.

An example of the simplest run: **azgcorr -p 5 5 -1 a1.hdf -3 a3.hdf**

This will use navigation and level 1 data on file a1.hdf and correct and output an image to file a3.hdf with a 5 metere square pixel size. By default UK National grid coordinates will be used and all input bands will be processed.

The program has potentialy long run times so running from a shell script that includes creating an output file compatible with an image processing package used for anyalysis, makes for a convienient background or overnight batch run.

It is of course understood that there are some advantages in being able to run the program, perhaps on restricted data sets, in a semi interactive mode, even to the extent of instant screen display. Work is underway to provide a complete interactive version during 2003.

4.2 Internal data files used by azgcorr

It was decided from the start of the Azimuth Systems Scanner processing System (AZSPS) , of which azgcorr is one of a dozen programs, to use the NSCA HDF scientific file format. This offered certain advantages of compatibility and access to basic file handling and data utilities. AZSPS currently uses **HDF4 of release 4.1r4.**

Full details can be obtained from the main HDF web site: http://hdf.ncsa.uiuc.edu/

The HDF format has considerable flexibility but only a basic subset has been used to create a file with a two level hierachy. Data items (Vdatas), which may have single values or vectors are grouped together to form Vgroups. On the AZSPS implementation Vdatas have been used for all items, which are limited to 1 dimension, except main image data which is stored as a 3 dimensional SDS (scientific Data Set item). Every data item is identified by a name and this is used elsewhere in this document to refer to items.

These AZSPS HDF files can be accessed in user software using the appropriate HDF libraries. NSCA provide utilities for viewing data item contents and items. The AZSPS utility program is supplied which allows for general listings, ascii files of multiplexed vector information and application specific files containg image data; BIL, BSEQ, GeoTIFF and TIFF are cater for. See: **azexhdf** user guide for more details.

The HDF files used in **azgcorr** contain all the navigation and scanner image data as well as all the related metadata items for a site. The following strategy has been adopted for AZSPS file contents:

a) all post processed navigation and scanner image data is contined in a level 1 file
- this will be a level 1a if no navigation is present or 1b with navigation
- a file will only contain data for one scanner and for one site

b) a Level 1b file processed by **azgcorr** may be used to generate a Level 3 file
- this will contain all the navigation and meta data items of the Level1b
- it will NOT have the level 1 image data present
- it will have the geocorrected image data
- it will have a mapping MP vgroup with mapping details used in the geocorrection

4.3 External data files used by azgcorr

azgcorr may be supplied with a few binary files containing correction grids for certain map projections and for spheroid to geod corrections. The user only has to supply the approriate parameter that gives the file path to these.

Other files which may be needed are user supplied digital elevation models (DEMs). These may be from topographic mapping, LIDAR or other sources. Details of their use is in the section on "how to use DEMs" as well as the DEMs in Option and Parameters below.

4.4 System requirements and Practical aspects of running the program

Versions of **azgcorr** and any support utilities can be supplied for use on Sun workstations under Solaris version 2.3 or higher and PCs running any version of Linux. In either case the minimum system configuration should be:

32 Mbyte of RAM, hardware floating point, 2x the maximum image file size of free disc space, a roll partition of at least twice the size of the RAM. Processing speed is directly related to CPU floating point performance (ie therefore CPU clock rate) and disc access rates.

With the amount of data and calculation required, correction of all bands for even a moderate sized site can take some time so the following details will help to avoid wasted time.

azgcorr run times will be **extended** by:

a) increased number of bands
b) increased number of scan lines
c) reduced pixel size,
d) presence of DEM
e) presence of other programs running on the CPU
f) amount of useable memory
g) shortage of disc space for output file

azgcorr may run out of memory with an inappropriate combination of:

a) too small pixel size, and...
b) diagonal flight line, and...
c) too many input scan lines
d) too small a ‘roll’ partition on Sun or Linux

The main points to note when running **azgcorr** is its potentially long run time. Users are advised, until they obtain a feel for these times, to restrict the number of bands selected for correction and to use an output pixel size no smaller than 5 metres. Run times are several times longer if a DEM is present; typical times for ATM are 20 minutes per 1000 scans per band on a Sparc 5.

The program allocates dynamically many large buffers depending on the direction of the data and the output pixel size. Memory is inversely related to the pixel size. The program will halt with an error message if too little memory is available. The program gives the total size of buffers allocated in the summary listing.

It is important to note on a Sparc workstation that the amount of useable memory (assuming a user has no installation restrictions) is about twice the actual RAM provided the disc swap partition is large enough for all tasks trying to run concurrently.

5 Applications of azgcorr

This section describes how to achieve desired results using the various control parameters.

Throughout the section, for clarity, on local file paths will be given, the user may use full paths for any file in their place. There are no defined filnaming requirements but we tend to use hdf as the HDF file extensions, a?? for ATM data and c?? for CASI/ccd scanner data.

To avoid confusion the level 1 data considered in examples below is assumed to have navigation all on WGS84.

The program may only used for the period and on the system or systems it is licensed for, if any of these criteria are not met an error message will appear and the program will terminate.

5.1 to obtain online program help

azgcorr	with no parameters, will show the program version and basic run requirements
azgcorr -help	will give an uptodate concise description of all parameters

5.2 basic correction

azgcorr -p 5 5 -1 a1.hdf -3 a3.hdf **ex1**

Image level 1 input is from a1.hdf, desired pixel size is 5 metres square and image output will be on a3.hdf. Important defaults whcih would be applied are: map projection would be UK National Grid 1995 version and all input bands would be corrected; image would use bicubic interpolation.

To limit the number of bands:

azgcorr -p 5 5 -bl 5 3 2 -1 -1 a1.hdf -3 a3.hdf **ex2**

would give 3 ATM bands suitable for a pseudo RGB image, these would be in R G B order on the a3.hdf file.

5.3 changing the map projection – no datum shift required

azgcorr -mUK99 osgb99 rest as ex2 **ex3**

Now the 1999 version of the UK National grid will be used, projection correction values will be from file uk99grid.

Other projections not requiring specific datum shifts are: Dutch and New Zealand; the shift from WGS84 is built in to the conversion.

5.4 changing the datum shift and map projection

This will be required in the cases where the desired map projection does not include an integral shift (the majority) or an accurate local shift is being used.

azgcorr -d7 0 -113.7 57.1 -98.4 -0.05 0.18 -1.7 1.28
-mUTM -7 **then as for ex2** **ex4**

Here the Transverse Mercator projection has been selected with a user central meridian of 7 degs west. A (fictitious) 7 point datum shift has been supplied and the default spheroid of International /ED50 has been used for both the datum shift and projection. Origin of the projection is at the equator and grid coordinates go from 0 at the equator northwards and form 50000 at 7 degs west. Commonly used datum shift and spheroid values are described in Appendix A

5.5 improving mapping accuracy without a DEM

Positioning based on WGS84 provides the latitude and logitude of the scanner as well as its height above the WGS84 spheroid. With the default settings **azgcorr** projects the corrected image to zero above the spheroid; for most sites this will be in error, so for coastal or relatively flat land sites where no DEM is available an improvement in mapping accuracy can be obtained by applying a spheroid to geoid correction form the internal tables or an external file.

azgcorr -hsu	**then as ex2**	**ex5**
azgcorr -hsu -es gsepfile	**then as ex2**	**ex6**

The first example assumes UK based data so the internal table can be used; the second supplies a file, which may cover any of the globe.

5.6 using DEMs all consistent coordinates

As descussed in detail in section **3.4** above DEM grids have to be consistent with the datum shift and map projection selected. This will be the case for DEMS obtained form local maps or mapping agencies.

azgcorr -mUK99 osgb99 -eh sitegrid	**then as ex2**	**ex7**

The DEM, on file sitegrid, is already UK99 and contains a file header describing the contents. The issue to watch is that the grid completely surrounds the image data; if it does not the missing parts will be extrapolated level and parts of the image will not fit a map accurately. Watch for the DEM limits message from the program.

5.7 using LIDAR DEMs no map fit required

If the DEM is generated but not controlled to the local datum eg. from scanned photos or LIDAR care has to be taken to avoid, what can be, large mismatches.

If the scanner aircraft and the LIDAR aircraft are both gps positioned two choices are possible: a) if the resultant corrected image does not need to match (well) an existing map; then the LIDAR data must be kept in WGS84 coordinates and use:

azgcorr -dNO -mTMw -3 -eh lidardem	**as ex2**	**ex8**

No datum shift if enforced and a tranverse mercator projection is used with default parameters EXCEPT the spheroid is WGS84 and the central meridan is 3 west (-3)

5.8 using LIDAR DEMs, best fit required

This will require that the LIDAR DEM grid is accurately processed to fit the local map at the desired scale. So, for a UK example, once this is done then **ex7** will apply.

5.9 controlling output image interpolation

Options are provided to do the two passes of the interpolation using one of three methods: a) cubic spline, b) linear and c) nearest neighbour.

By default cubic spline is used resulting in a smooth image "surface" but will generate pixel values intermediate to adjacent ones which may have DN values not in the original image.

For uses such as classification, nearest neighbour may be more appropriate, as no new values are created.

Users are encouraged to try different methods to see how which best fits their application. It worth noting that linear and nearest neighbour are much faster than cubic.

If aircraft motion was extreme, for any reason, it is possible for the edge of, particularly ATM images with their large field of view, to open up. This will be seen as black "inlets" encroaching into the image. Parameter **-g gm gr** can be used to control this. **gm** is the size in pixels of a the minimum gap, ie if a gap of greater than this occurs it will not be interpolated across. **gr** is the count of pixels considered as a run of good pixels.

5.10 BIL input of image data

Image data may be extracted from a level 1b HDF file, accessed by a user program to create an equivalent size and layout BIL file which is then input to **azgcorr** in place of the Level 1b data for geocorrection; a run sequence to do this would be:

azexhdf -bl 2 3 5 -1 -h a1.hdf -Bs -B a1raw.bil

userprogram [-Bs a1raw.bil.stats] -Bin a1raw.bil -Bout a1new.bil

azgcorr -1 a1.hdf -B 1 1 1.0 0.0 0 -Bi a1new.bil -3 a3.hdf

The first **azexhdf** exports 3 bands in BIL layout to file a1raw.bil, by selecting -Bs a second file is created a1raw.bil.stats which maybe input to a user program to obtain the details of the BIL file without having to manually tranfer them, see Appendix ??

userprogram optionally uses the stats file and input image data from a1raw.bil performs some calculation, which for this example only creates 1 band, and outputs the result image to a1new.bil. It does matter if this file is described as BIL or BSEQ as it only has one band, both will be identical.

The **azgcorr** run still requires the original level 1b HDF file, a1.hdf as well as the user created BIL file, a1new.bil and the parameters describing this file. These indicate there is 1 band, data in floating point, no rescaling required and standard blank area infill required. Corrected output will be to a3.hdf.

Note that a current restriction is the number of lines and pixels must the same throughout, so the user program must not change the number of lines or pixels.

5.11 typical complete run

Batch script file contains:

rm a3.hdf

azgcorr -mUK99 uk99grid -eh DEMforsite -p 2 2 -bl 5 3 2 -1 -1 a1.hdf -3 a3.hdf

azexhdf a3.hdf

azexhdf -bl 1 2 3 -1 -h a3.hdf -G a3.tif

a): The old level 3 files are first removed.
b) **azgcorr** run does correction on UK National grid 1999 version and uses a local DEM. Pixel size is 2 metres and a three band RGB set is produced. Interpolation is left to cubic default.
c) first **azexhdf** just generates a content listing of the level 3 HDF file
d) second **azexhdf** creates a GeoTIFF file of the level 3 3 band image, note this has 16 bits per band; this will be compatible with ERDAS 8.5, ERMAPPER etc.

6: Program execution Options and Parameters

The description below expands on the concise version obtained in the standard unix usage method obtained by typing: **azgcorr -help**

It should be noted that the most up to date information is from the usage version.

Notes on the description below:

a) Letters preceeded by minus signs are the parameter names as summarised in the Usage listing.
b) Filenames always implies full unix paths.
c) Command line parameters and values may be in any order.
d) Latitude and longitude values in signed decimal degress are -ve for south and west.
e) All units of distance are in metres.
f) Option requirement in typical runs are optional unless stated.

option: **-1 fn** **level 1 HDF file path**

fn = input Level 1 HDF file path

requirement: **MANDATORY** default: NONE

option: **-3 fn** **level 3 HDF file path**

fn = output Level 3 HDF file

requirement: **MANDATORY** default: NONE

option: **-p dx dy** **Output pixel size**

Output pixel x, y sizes in metres.

Requirement: **MANDATORY** default: NONE

option: **-B b t s o f** **BIL or BSEQ file content details**

b = total bands on file
t = number type on file, 0= uint16, 1= float32
s = scale
o = offset to convert B file values for geom correction and saving as uint16, v = p * s + o
f = fill value for bad pixels; good pixels are < f
if f = 0 the default values of 0 and 0xffff (uint16) or 10e30 (float32) are assumed

requirement: MUST be used if -Bi or -Bs are used
defaults: b NONE; s = 1.0; o = 0.0

option: **-Bi fn** **BIL file path**

fn = BIL input file Default: none

option: **-Bs fn** **BSEQ file path**

fn = BSEQ input file Default: none

d... Geodetic datum shift details

For details of commonly used data shift values see Appendix A

option: **-dNO** **No datum shift performed**

No datum shift is performed, data remains in WGS84 throughout processing.

option: **-d95** **OS 1995 datum shift method applied**

Ordnance Survey 95 method using GRS80 datum. See Ordnance Survey publication:
National Grid/ETRF89 Transfromation Parameters. Geodetic Information Paper No. 2. 2/95 V1.2

This is the default if no -d option is used.

option: **-dDUTCH** **for Netherlands National Grid**

No parameters

option: **-d7 sc a p2 dx dy dz rx ry rz sc** **7 parameter Bursa-Wolff shift**

Applies a 7 parameter Bursa-Wolff single point transformation

sc = spheroid code
= -1 if a and p2 are supplied, 0= Int (Hayford 1950, 1= Airy 1830 (UKNG);
a = semi-major axis
p2 = semi-minor axis or reciprocal flattening or eccentricity (metres)
dx,y,z = origin shift in metres
rx,y,z = axis rotations in secs
sc = scale excess in ppm, ie scale = 1+sc/1000000

There are no numeric defaults except as mentioned.

-m... Map projection details

For details of map projection and required parameters see Appendix B

If -m is not supplied the built-in conversion method UK National Grid 1995 is used.

option: **-mUKNG** **TM set to UK National Grid**.

This uses the Airy 1936 spheroid and has no built in spheroid-geoid correction and requires a seven parameter datum shift to be applied; see -d7 above and datum shift values in Appendix A

option: **-mUK99 fp** **TM set to UK Nation Grid 1999 method**

fp = file path to OSGB99 correction file

The details of this method, using OS supplied correction grids OSTN97 and OSGM91 are described in OS publication, User Guide v1.2 - 12/1999.

option: **-mUK02 fp** **TM set to UK National Grid 2002 method**

fp = file path to OSGB02 correction file

This method is similar to the 1999 one but uses an iteritive reverse conversion and a correction grid described are being more accurate. The grids released by the OS have been cut to about 10Km offshore around coasts. The grid supplied for use in **azgcorr** has been filled in these offshore areas by adjusted values from the 1999 method grid.

option: **-mIRNG** **TM set to Irish National Grid**

As of **azgcorr version 4.0.0** the latest (02/2003), accurate conversion method for Ireland has not been included, contact Azimuth Systems for further information.

option: **-mUTM cm** **UTM with central meridian**

TM set to UTM with supplied central meridan (longitude) = cm (signed decimal degrees)

option: **-mUTMZ zo** **UTM to zone zo (1-60)**

Zones are 6 degrees wide and numbered 1 to 60; 1 is 180 west to 174 west with central meridan at 177 west, UK is in zones 30 (3 west) and 31 (3 east)

option: **-mTMw cm** **TM using WGS84 spheroid**

This option is provided to allow a quick look at non-UK data without having to fill in all the parameters to keep the map projection in WGS84 spheroid.

option: **-mTM s1 s2 lao lno sc nor eor** **Comprehensive TM**

Transverse Mercator with user supplied parameters.

s1 = spheroid code or semi-major axis (a) 0= INT, 1= Airy, 3= WGS84
s2 = semi-minor (b) or reciprocal flattening (f) or eccentricity (e^2)
(set this to 0 if s1 is a spheroid code)
lao = projection origin latitude
lno = central meridian (longitude) (cm)
sc = scale factor at cm (typically 0.9996)
nor, eor = grid coords at origin and cm

No defaults are provided.

option: **-TMS** **forces use of southern hemisphere for TM**

option: **-mLAM h s1 s2 lao lno eor nor la1 la2** **Lambert Conical**

Lambert Conical Orthomorphic with one or two parallels.

s1, s2, lao, lno, eor nor as TM above

h = hemisphere N=north, S=south
la1, la2 = two standard parallels (lats), if la1=la2 single parallel projection used

option: **-OM....** **Oblique Mercator**

option: **-OM do s1 s2 sc xor yor lac la1 ln1 la2 ln2** **(if do = 1)**
-OM do s1 s2 sc xor yor lac lnc azc **(if do = 1)**

do = defining option
= 0 for centre and 2 points on centre line
= 1 for centre and azimuth of centre line
s1 = spheroid code or semi-major axis
s2 = semiminor axis (b), reciprocal flattening (f) or eccentricity (e^2)
sc = scale factor at centre of projection
xor, yor = grid coordinates at origin
lac, lnc = lat/long at centre
la1, ln1 = first point on centre line
la2, ln2 = second point on centre line
azc = azimuth of centre line (east of north)

option: **-RSO....** **Rectified Skew Mercator**

parameters as for Oblique Mercator, above

option: **-NZ** **New Zealand projection**

New Zealand projection on International spheroid (Hayford 1910), no parameters

option: **-DUTCH** **Netherlands National Grid (Rijksdriehoeksmeting - RD)**

projection on Bessel 1841 spheroid; no parameters

a... Corrected image alignment relative to map

option: **-an** **North up**

Default if -a.. is not used

option: **-af** **Rectangle centred on flight line**

option: **-a az** az = user clockwise angle from grid N

option: **-pab** **Output pixel coordinate alignment**

If this option is present pixel coordinate limits are aligned at bottom left (SW) corner. If this option is not present coordinate limits are aligned at the centre of pixels.
NB1: aligning at bottom left implies final image limits are to the outside edge of the peripheral pixels
NB2: CASI spectral, enhanced spectral and ILS coords are always returned pixel centred

option: **-r rv** **Coordinate rounding**

rv = coordinate rounding value, def: is pixel size rounding is to multiples of rv

option: **-ro xm ym xx yx** **Enforced output limits**

Output image enforced x,y limits (grid coords): allows different data sets to be matched
: ** NB: wrong values may extend the image and cause runtime memory problems and large file size

h... Aircraft height control

option: **-h ht** **Constant height**

ht = aircraft height above ground

option: **-hn** **Navigation height used**

Selects the use of GPS navigation height. This is the default if no -h is used.

option: **-hs sc** **Navigation height with correction**

Same as -hn but allows a user constant height correction to be made.

sc = height correction to be added to aircraft hgt

Requirement: options -hn or -hs MUST be used with DEM and geoid-spheroid correction.

option: **-hsu** **Geod-spheroid height correction**

height correction for WGS84 geoid-spheroid applied as a constant based on map centre

option: **-l st en** **Input scan lines to process**
option: **-ls sts ens**

Scan line numbers to limit processing, st and en are scan counts in the image from 0 and sts, ens are original instrument allocated scan numbers in the range of items CAsscan, CAescan (CASI vgroup) or ATsscan, ATescan (ATM vgroup).

Default: with -l or -ls missing is to process all scans on the input file.

b... Input bands to process

option: **-bl b1 b2 ....-1** **List of input bands to process.**
option: **-br b1 bn** **Inclusive band range to process**

Note that if less than the total bands are processed output bands may be reordered. For example:
with -b 5 3 2 -1
the output image bands will be 1 = input band 5, 2 = input band 3 etc

Default with no -b option is to process all input bands.

c... CASI processing options

option: -call process all present data in default modes
option: -cspa DO NOT process IMG if spatial, def: process
option: -cils process ILS, def: do not process
option: -csrc process SRC, def: do not process
option: -cspe process spectral, def: do not process
option: -cspi process spectral as complete image
option: -cspw process enhanced spectral at minimum width, = default
: ie, not equal in size to SRC image
Default for ILS and spectral is to save pixel coords as extra bands and apply no image interpolation

option: **-cc o p fv** **CASI ccd and lens details**

CASI ccd/lens details to replace program defaults...

o = optic axis (nadir) pixel n or n.5, ie: 230 or 225.5 but not 124.3
p = port pixel 0= pixel 1is on the port side, 1= max pixel is on the port side
fv = lens field of view in decimal degrees

option: **-ccd o p fv pfv tp : general ccd details to replace file defaults**

o = optic axis (nadir) pixel (decimal)
p = port pixel 0= pixel 1, 1= max pixel
fv = lens field of view in degrees
pfv = field of view port pixel to optic axis
tp = total pixels in field of view

option: **-cca pt : load casi/ccd pixel view angle table from external file**

pt = file path/name for pixel view angle table

Angles are from port to starboard in flight direction, in decimal degs and must equal in number the current viewed full ccd pixels for all processing

i... Output image interpolation control

option: **-ic sm** **Bi-cubic**

Method uses a cubic tensioned spline, sm is the spline tension.

This is the default if -i is not used.

sm = smoothing value (0.001-50.0) def= 1.0, 0.001 is very smooth, 50 is linear interp

option: **-il** **linear**
option: **-in** **Nearest neighbour**
option: **-il2** **second pass interp is linear**
option: **-in2** **second pass interp is nearest neighbour**
option: **-ic2 sm** **second pass interp is cubic, sm = smoothing**

option: **-it g** **: thinning option on second pass interpolation**

g = multiples of pixel spacing, default = 0.5

Pixels are omitted if closer together than g

option: -**g gm gr** **Image gap control**

gm = gap size in multiples of pixel size, ie gap (metres) = gm * pix_size
gr = good data run, which will be interpolated

These controls only affect the edge of the image as gaps rarely occur elsewhere. In general the defaults should be used.

Defaults: gm = 4, gr = 4

e... Digital Elevation Model (DEM) control

option: **-e fn** **Digital Elevation file**

fn = DEM file path, may be repeated: 8 times, file(s) may be NTF contour OR grid OR internal grid format **** but not mixed**

option: **-eg gr** **DEM grid increment**

For use with NTF contour files, defines the saved DEM grid increment, should be >= 2* pix inc.

Default: 10 metres

option: **-ef** **DEM force slow search for ground intersection**

This option is occasionally needed in areas of rapid topographic change (steep slopes).

option: **-ez v** **DEM fill grid edge**

v = value to fill empty grid edge nodes

Default: fill with nearby values

option: -**ed or c r xm ym xx yx gi** **flat file ascii DEM definition**

This defines the contents of a flat file containing DEM values. Files may have no header, in which case -e fn gives the filename or a header may be used to avoid using this -ed option, in this case use -eh to give the file name.

or = data order, =0 rows(x) S->N, =1 rows N->S
c = cols
r = rows
xm, ym = SW corner coords;
xx, yx = NE corner coords
gi = grid increment

grid values on file must be separated by space(s) and may have decimal points
NB: only ONE file may be present

option: **-eh fn** **flat file with header**

fn = DEM file path, for flat file with a header

header is the -ed items separated by spaces... eg: 0 512 1024 0 0 511 1023 1.0

option: **-es fn**

fn = geoid-spheroid separation grid file path
if fn = NO, no geoid-spheroid correction will be applied

Default if -es is not present is to use program built in g-s values which cover UK:
SW: 49.75 N 7.5 W to NE: 60.75 N 2.75 E
Sites outside this range must use a g-s file

option: -**n..** **Navigation control**

option: **-nac p r h** **sign control of attitude items**

p, r, h = 0 for use item without sign alteration
= 1 for use with signs reversed
= 2 for don't use, ie set attitude item to zero
(-nav may them be used to give a constant value)
NB: normal sign convention assumes: pitch is +ve nose up
roll is +ve port wing up
head is +ve clcokwise from nose

option: **-na p r h** **attitude corrections to be added**

p, r, h = values in signed degrees to be added to the attitude value after applying option in -nac

option: **-ns** **reverse scan direction**

scan direction is assumed to have pixel 0 from the input file on the starboard side of the field of view

option: -**v** **verbose listing request**

7 azexhdf data export utility

7.1 introduction

azexhdf allows the user to extract, list or reformat selected data from an AZSPS HDF file. Output files may be in one of several standard layouts and formats for transfer to image analysis and display programs.

Spported output formats are **BIL**, **BSEQ**, **Sun-raster**, **TIFF**, **GeoTIFF** as well as ascii, space separated multiplexed vector flat files.

Selection of data may be by HDF file item name, spectral bands, pixel or line limits.

7.2 basic use

Use: At unix prompt type: azexhdf [options] [-h] hdf_file_path

Usage information: (obtained by executing program with no command line parameters)

7.3 options and parameters

option: **-h fp** **hdf file path**

fp = file path for hdf file to access

option: **-hg vg** **vgroup to list**

vg = Vgroup name for single vgroup access; -hg not present = all vgroups listed : default

option: **-hd vd** **vdata to list**

vd = single vdata to list file

option: **-B fp** **convert image data to BIL binary file**

fp = file path for created file

option: **-BS fp** **convert image data to BSEQ binary file**

fp = file path for created file

option: **-Bv** **verbose detail listing for conversion**

switches on verbose listing mode for BIL or BSEQ file creation

option: **-Bs** **requests output header/stats file**

creates a header file during a BIL file output; must be used with -B, file will be fp.bil.stats

option: **-Bh c** **requests output histogram to header/stats file for all data**

c = number of columns in histogram, c = 0 gives 256

option: **-Cx fp** **create binary file with CASI spectral and ILS**

fp = file path for created file

file contents for each image pixel (0-pixels) and each image line (0-lines) coordinates are pairs of xy's grid coords, format is tenths of metres in signed long
NB: must be run separately from BIL; -p may be used

option: **-Cr fp** **as for Cx but coords are col, row pairs to match**

the row column pairs match the SRC image, format is uint16
NB: must be run separately from BIL; -p may be used

option: **-T fp** **convert any level image data to TIFF file (.tif)**
option: **-G fp** **convert level 3 image data to GeoTIFF file (.tif)**

fp = file path for created file

1: these files are TIFF level 6.0 or GeoTIFF 1.1.4 pixels are band interleaved by pixel BIP and there are the requested no. of bands samples per pixel in 16 bit unsigned.
2: Note that some readers may not allow more than 3 bands.
3: Only TM/UTM/UKNG projections are supported in this version.

option: **-d dn** **image data item name if not default**

default is to use the standard item for ATM and CASI

option: **-S fp** **convert image data and output to Sun raster file**

fp = file path for created file

option: **-c r g b** **band nos for colour image Sun raster file**
option: **-m c** **band no for monchrome image Sun raster file**

option: **-p p0 pn l0 ln** **image patch limits, pixels and lines**

p0 pn = pixel limits, in the range, 0 to number pixels in the image
l0 ln = scan line limits, in the range 0 to lines in image

This can be used for Sunraster, BIL and image item listings

option: **-ph** **does image listing in hex**

Switches image listing between integer and hex

option: **-pbseq** **if present does image list in BSEQ order**

If not present (default) image list in BIL order

option: **-po** **only image listing done**

Suppresses listing of other HDF data items.

option: **-r** **output DN values as radiance using default scaler**

Default is to save image items unchanged from the HDF file.

option: **-rm m** **user supplied multiplier for DN scaling, for BIL output**

m = user supplied multiplier

option: **-bl b0 b1 ... -1** **select bands to be converted to output**

b0.... = list of band numbers (1-bands) and in the order for saving

option: **-br b0 bn** **select bands by range**

bo bn = bands will be saved from b0 to bn

option: **-l** **line order reversed on output to files**

Scan lines are ouput by default as:
HDF levels 1 and 2 : scan 0 first
HDF level 3 : northern most scan first
If -l is present this order will be reversed.

option: **-v....** **vector saving/listing options**

option: **-vf fp** **filepath for complete vector output**

option: **-v max** **max items to list for vectors in summary listing, def: 1**

NB: this is for listings only.

option: **-vn item** **HDF VData vector data item name**

item = VData name, repeat use for several items (NB: max of 12 items)

NB: this is for VData items only NOT SDS image items.

option: **-vi st en** **vector index limits to save file**

st en = start and end index (0->) to save from HDF VData items to file

option: **-vq fmt** **format for qual vectors items**

fmt = C format description for navigation qual item listings, default is %08lx

option: **-vs** **add scan number in col 0 of multiplexed output**

This is to be used with NVscnum and NVscsecs only.

option: **-vp n0 n1 .. -1** **user supplied list of decimal places**

n0... = no of decimal places in order of vector vn items

This is to control ouput listing of a set of multiplexed vectors
if only n0 is given this will apply to all items;
defaults dps are: v < 90 : 5 else 5,: except ??lat? and ??lng? are 7 dps

option: **-vm** **ALL requested vectors to be output multiplexed**

NB: vectors must be from the same Vgroup and of equal length,
eg: pitch roll and heading

Notes:

1: Filenames can be complete paths.
2: Vgroup and data item names are case sensitive.
3: Band numbers are 1 relative.
4: Pixel and line patch limits are zero relative.
5: for version 2.0.0 onwards, local libraries for TIFF and GeoTIFF are not required

7.4 applications of azexhdf

7.4.1 HDF file contents listing

typing: **azexhdf [-h] hdf_file_path** at the unix prompt (-h is optional)

Will obtain a summary listing to stdout. Parameters **-hg** and **-hd** with appropriate VGroup and data item names can be used to retrict the listing to one VGroup or just 1 data item.

By default vector items listings are limited to 5 items at the start of the vector and the last one, if there are more than 5 values. To list more of the values use option **-v** to get the required number from the start of the vector or **-vi** to get a selected part from the middle.

eg: **azexhdf t1.hdf** Will give a summary listing of all items on t1.hdf

eg: **azexhdf -hg NV -hd NVlat -v 100 t1.hdf**

Will get a listing of the first 100 and last values of the NAV VGroup vector containing aircraft latitudes.

For image items stored as SDS listing are obtained by using the options: **-bl** to select one or more bands and **-p** to define a pixel patch. By default the item listed will be ATdata for ATM VGroup and CAimage for CASI VGroup; other items can be selected using option: **-d**

7.4.2 Mulitplexed vectors

Selected vectors can be listed or output to an ascii file multiplexed. This is only valid if the items are related and exactly match in length and gaps. A typical use of this is to get navigation items or scan sync items. **-vf** gives an output file; **-vm** selects multiplexed mode; and repeated use of **-vn** gives the required items. Note: this is for none SDS items only.

eg: **azexhdf -vf nav.dat -vm -vn NVtime -vn NVlat -vn NVlng -vn NVhgt t1.hdf**

Wiill obtain a 4 column file with all entries of GPS time, latitude, longitude and height.

7.4.3 HDF file reformatted to BIL or BSEQ

Image items are extracted and reformatted to BIL or BSEQ files with the options **-BIL or -BSEQ** to select the file format, along with an appropriate file path to contain the output.
The following optional parameters can be used to modify the output: **-d** to select a none default item (ATM is ATdata, CAS is CAimage); **-bl** to select one or more bands; **-p** to limit pixels and lines; **-Bs** to get a summary statistics file and **-Bh** to get a histogram for each selected band. **-Bv** will obtain extra coordinate details for level 3 files.

BIL and BSEQ output files data entries are in the same format as level 1 files, ie binary unsigned integers. Pixels are output with file indexed zero first and lines, with line indexed zero first. Bands are output in the order requested by parameter **-bl**, eg: -bl 5 3 2 -1 would give these three bands in order 1, 2, 3 on the output file; if the file was BIL the sequence would be:

line 0 band 5 pixels 0 to n
line 0 band 3 pixels 0 to n
line 0 band 2 pixels 0 to n
line 1 band 5 ..... etc

Line and pixel order imply that a level 1 file will be in flight direction down the file, with pixel zero on the right. By deafult, a level 3, north up file will be going north down the file, with pixel zero to the west; directions can be changed in level 3 processing. Option **-l** can ve used to reverese the line order convention for output to a file.

7.4.4 Sun raster output

A SunRaster format file can be created from 1 or 3 selected bands to give an image viewable using utilities such as imagetool or XV. Note that if the selected image is beyond a certain size or contains too may colour levels these utilities will resample and remap the pixels.

Option **-S** selects the output format and provides the output file; **-c** or **-m** provides the band from the HDF file and selects RGB colour or monochrome output file format.; **-p** can be used to restrict the image patch.

eg: azexhdf t1.hdf -S a.sunr -c 5 3 2

Will obtain a SunRaster RGB file for bands 5 for red, 3 for green and 2 for blue of the whole default image item on t1.hdf.

7.4.5 TIFF output

A TIFF file containing 1, 3 or more bands can be created using the option **-T fp** . Data limiting options as for **-BIL** apply to select bands, pixels and lines. Pixel format is limited to UINT16.

The created file can be used in many image display packages but not all can handle more than 3 bands.

7.4.6 GeoTIFF output

A GeoTIFF output file can be created, as for TIF but can only be from a level 3 file as the GeoTIFF file requires geolocation data for a rectangular image.

GeoTIFF files can be input into most of the main remote sensing image handle packages, eg: ERDAS, ERMAPPER, etc. ERDAS from ver 8.5 will accept and allow viewing of more than 3 bands in the file.

GeoTIFF (ver 1.1.4 in azexhdf 2.0.0) has some restrictions in defining map projections which affect some local European projections. For the UK currently only the basic pre 1995 method for UK National Grid is supported. When images are transferred to ERDAS and used with other images or vector data this should be remembered.

7.4.7 Limitations and error messages

azexhdf may not work correctly and may well crash if the input hdf file was created by a previous program run that terminated with an hdf error. This is one of many deficiencies in the HDF system which is unable to detect corrupted or improperly closed files.

azexhdf will correctly report if an input file is missing or not an HDF file. It will then terminate.

A Commonly used Datum Shift and Spheroid values

Datum shift (-d) and map projection (-m) options both may require numeric values for spheroids and datum shifts, commonly used values are supplied below.

These are supplied without any claim as to their accuracy - it is the user's responsibility to verify accuracy and relevance to their use.

Spheroid values

Spheroid name	*AZSPS code*	*A*	*1/f*	*Notes*
International	0	6378388.00	297.00	Hayford 1910
Airy 1830	1	6377563.3963534	299.32496459380	UK National Grid
WGS 1972	2	6378135.00	298.26	
WGS 1984	3	6378137.00	298.257223563	
Everest 1830	4	6377276.345	300.8017	
Everest revised	5	6377298.556	300.8017	
Malayan 1830	6	6377304.068	300.8017	
Bessel 1841	7	6377397.155	299.1528128	
Clarke 1858	8	6378293.645	294.2600	
Clarke 1866	9	6378206.400	294.9786985	
Clarke 1880	10	6378249.200	293.4660213	IGN
Clarke 1880	11	6378249.145	293.465	MOD
Helmert 1907	12	6378200.000	298.3	
War Office	13	6378295.000	296.0	
Krassovsky 1940	14	6378245.000	298.3	
Hough 1956	15	6378260.000	297.0	
Fischer 1960	16	6378155.000	298.3	Mercury
Fischer 1968	17	6378150.000	298.3	Mercury revised
NWL 8D	18	6378145.000	298.25	
Australian National	18	6378160.000	298.25	
South American 1969	19	6378160.000	298.25	
Ghana National	20	6378295.000	296.00	
OS GB GRS80	21	6378137.000	298.25722154381	
GRS80	22	6378137.000	298.25722210100	

Datum shifts

These are all **FROM WGS84 TO** the named spheroid. d's are in metres, r's in seconds, sc in ppm.

spheroid	*dx*	*dy*	*dz*	*rx*	*ry*	*rz*	*sc*
Airy 1830	-446.446	125.157	-542.060	-0.1502	-0.2470	-0.8421	20.4894

B Map projections and required parameters

C BIL file and BIL.STATS file details

The standard flat file format used for remote sensing data is **Band Interleaved by Line** (**BIL**). For historic reasons this has no header to describe the file contents nor data value format. **azgcorr** can also generate similar files in **Band Interleaved by Pixel (BIP) and Band Sequential (BSEQ)** but these are used less often.

azexhdf can generate BIL files and an associated AZSPS file that contains, in readable text, a description of the BIL file contents. This description file is follows no standard, as there is none, but may be used and adapted for user purposes. There is also an option to output a per band histogram to this file. See **azexhdf** running instructions for how to create the files.

BIL format means that for each scan line all pixels in sequential order acroos the scan appear in band order for the scan, ie:

```
line 0    band 0  pixel 0          pixel n
          band 1  pixel 0          pixel n
          .......
          band m pixel 0           pixel n
line 1    baad 0  pixel 0          pixel n
.......................
etc
```

BIL files output by **azexhdf** have no pack bytes at any place in a band or line.

If the AZSPS header information file is requested it consists of a set of name and value pairs, separated by spaces, describing the contents and layout of the BIL file, these are:

```
scanner  [AZ16, CASI etc]
item  [name of image item from HDF file: Atdata, CAimage etc]
proclevel  [1, 2 or 3]
bfile   [the BIL file being decribed]
pixels   p   bands  b   lines  l       [ p, b and l are integer total for each dimension output ]
pixfmt  [ 0 = UINt16 and 1 = 4 byte float ]
radscale  [ -1.00 means unscaled ]
pixby  [ bytes per pixel ]
bandby  [ total bytes for a complete band ]
band   b  obnd  ob  min  m  max  x        [ repeated for each band in its output order ]
          b is from 1 to bands output,  ob is the original band number,
          min and max are the band DN limits excluding 0 and overflow values
xys    [ for a level 3 file this is the SCposimag vector items  2 to 7, see HDF description general note 5]
```

If a histogram was requested the following is present:

```
histcols  n     [ n is the number of columns in each histogram ]
```

then the following are repeated for each band output:

```
hbnd  b  hzer  z  hovf  o  hcol      [ b is band output, z is 0 column entry and o the overflow entries ]
```

[then histogram columns 10 per line]

A typical level 1 file would be:

```
scanner AZ16 item ATdata proclevel 1 bfile a1.bil
pixels 718 bands 1 lines 5167
pixfmt 0 radscale -1.00 pixby 2 bandby 1436
band 1 obnd 1 min 24531 max 24887
histcols 256
hbnd 1 hzer 0 hovf 0 hcol
  0 0 0 0 0 0 0 0 0 0   etc for rest of 1 band histogram
```

The level 3 file from the same data set is:

```
scanner AZ16 item ATdata proclevel 3 bfile a3.bil
pixels  2190 bands 1 lines 393
pixfmt 0 radscale -1.00 pixby 2 bandby 4380
band 1 obnd 1 min 24662 max 32310
xys  259176.0  291036.0 3.000 -0.000 0.000 3.000
histcols 256
hbnd 1 hzer 148652 hovf 0 hcol
  ..... followed by 1 band histogram
```

D AZSPS Level 1 and Level 3 HDF file details

The HDF layout used for the Azimuth Systems scanner processing system (AZSPS) is described below. A restricted subset of HDF interfaces has been used. All data items are only identified and accessed by name. A two level item hierachy is used; VDatas in single level VGroups. Data items are only stored as single dimension VDatas (with one or more values) or three dimensional scientific data sets (SDS) linked to particular VGroups. Data items can be read using general released HDF utilities or the supplied utility, **azexhdf,** HDF used in this release is HDF4.1r4.

Some items are application related and the user is refered, where relevent, to the appropriate processing program.

VGroups and contents

Nmeonic	name	contents
PRO	processing	details of the system used to create the file
MIS	mission	descriptive details of the flight site and site time and scan limits
NAV	navigation	all related but post processed navigation, linked to scanner data by gps time and scan number
SCO	scan coords	final per scan coordinates corrected to scan nadir and transformed to the scanner
MAP	mapping	datum and map projection details used to create a level 3 image
LV2	level 2	level 2 details
ATM	ATM	ATM data from original Daedalus system
ATM2	ATM2	ATM data from AZ16 system
CAS	CASI	CASI or other ccd scanner data

Navigation vector items are stored compressed, using a simple multiplier, which is also stored in the HDF file. This saves disc space without loss of precision. Image items are stored as unsigned integers, again scaled to best preserve precision. Optionally image items may be stored as floating point but file sizes will be doubled.

Using unix utilities, HDF files may be copied, moved or archived but NOT viewed, edited, concatentated or truncated.

Data items are described by name, data type, maximum number of occurences of the type and a brief descripton. Notes specific to a Vgroup appear after the items decsription for that VGroup and general notes appear at the end of the document.

VGroup: PROCESSING

Contains details of the file processing level, creation and authorship. Vgroup is created by SITEINIT, with PRlevel updated by appropriate programs.

Vgroup name: PRO
Vgroup title: Processing
Data item prefix: PR

Item name	type	maxv	description
PRdesc	C8	64	Vgroup description: Latest processing level of file
PRlevel	C8	8	Latest processing level of file
Prcdate	C8	32	File creation date
PRhostn	C8	64	Host name of creating workstation
PRhostid	C8	16	Host ID of creating workstation
PRsoftware	C8	64	Processing software copyright notice

VGroup: MISSION

Contains all pre-flight, operations and target delimiting values. Site limits may be either or both of time and scan and are inserted by SITEINIT. CASI details are inserted by CASCHK and are obtained from an analysis of the complete CASI data file or files.

Vgroup name: MIS
Vgroup title: Mission
Data item prefix: MI

Item name	type	maxv	description
MIdesc	C8	64	Vgroup description: Mission and site details from flight logs
MIprog1	C8	40	Vgroup 1st processing program name
MIprog2	C8	40	Vgroup 2nd processing program name
MIcopyw	C8	64	Data copyright notice
MIairc	C8	32	Aircraft name
MIpilot	C8	32	Pilot name

MInavig	C8	32	Navigator name
MIoper	C8	32	Operator name
MIbase	C8	32	Sortie base
MIdate	C8	16	Flight date
MIfltno	C8	32	Flight number
MIprojco	C8	64	Project code
MIpiaff	C8	64	Principal investigator and affiliation
MItarget	C8	64	Target name
MIfline	C8	32	Requestors flight line name/number
MIaspeed	C8	32	Airspeed
MItrack	C8	32	Track
MIalt	C8	32	Altitude
MIweath	C8	128	Weather
MIcloud	C8	32	cloud cover
MIland	C8	32	land type and amount
MIcomm	C8	128	Comments
MIfnum	I32	1	CASI field tape file number
MIaper	I32	1	CASI used aperture
MIscanner	C8	8	Scanner name (ATM or CASI)
MIslimit	I32	1	Site limit type flag, 0= none, 1= time, 2= scan, 3= both
MIsday	I32	1	Day number of site start time (1-366)
MIstime	I32	1	Time of site start (HHMMSS)
MIetime	I32	1	Time of site end (HHMMSS)
MIsscan	I32	1	Scan number at site start
MIescan	I32	1	Scan number of site end
MIlimits	C8	128	description of site limits

VGroup: NAVIGATION

Contains observed navigation from aircraft survey instruments and base reference station. Up to two sets of independent navigation sets can be saved with position and attitude with each set having independent timing. All times in seconds are consistent and are used to link navigation observations and scans. GPS data is inserted by azjps or azimport and scan sync by azjps, azatm or azcaschk.

VGroup name: NAV
Vgroup title: Navigation
Data item prefix: NV

Item name	type	maxv	description
NVdesc	C8	64	Vgroup description: GPS navigation and scan synchronisation data
NVprog1	C8	40	Vgroup 1st processing program
NVprog2	C8	40	Vgroup 2nd processing program
NVprog3	C8	40	Vgroup 3rd processing program
NVsys1	C8	40	Prime aircraft survey navigation system
NVsys1i	C8	40	Prime system infomation
NVsys2	C8	40	Secondary aircraft survey navigation system
NVsys2i	C8	40	Secondary system infomation
NVsys3	C8	40	Third aircraft survey navigation system
NVsys3i	C8	40	Third system infomation
NVbase	C8	40	Base reference station navigation system
NVbasei	C8	40	Base information
NVpos1i	C8	40	position set 1 information
NVatt1i	C8	40	attitude set 1 information
NVpos2i	C8	40	position set 2 information
NVatt2i	C8	40	attitude set 2 information
NVspher	C8	40	Spheroid name for aircarft navigation system
NVdatsh	C8	40	Datum shift applied to aircraft navigation system
NVtbase	C8	40	basis of all timiing
NVacor	f64	1	vector of aircraft nav posn to scanner offset
NVut2gt	f64	1	time correction used to convert NMEA UTC times to GPS time in seconds
NVjday	I32	1	Year day for site start
NVstime	I32	1	Time of site start (HHMMSS)
NVetime	I32	1	Time of site end (HHMMSS)
NVtime	sI32	var	Time of position set 1 observations (GPS dec secs)
NVutc	sI32	var	Time of position set 1 obseravtions (UTC dec secs)
NVlat	sI32	var	Latitude (dec degs)
NVlng	sI32	var	Longitude (dec degs)
NVhgt	sI32	var	Spheroid height (metres)
NValt	sI32	var	Recorded altitude above local datum (metres)
NVqual	UI32	var	position quality flags
NVasecs	sI32	var	Time of attitude set 1 observations (dec secs)
NVroll	sI32	var	Aircraft roll (positive right wing down) (dec degs)
NVpitch	sI32	var	Aircraft pitch (positive nose up) (dec degs)

NVhead	sI32	var	Aircraft heading (0-360 clockwise from true north) (dec degs)
NVaqual	UI32	var	attitude quality flags
NVtime2	sI32	var	Time of position set 2 observations (GPS dec secs)
NVlat2	sI32	var	Latitude (dec degs)
NVlng2	sI32	var	Longitude (dec degs)
NVhgt2	sI32	var	Spheroid height (metres)
NValt2	sI32	var	Recorded altitude above local datum (metres)
NVqual2	UI32	var	position set 2 quality flags
NVasecs2	sI32	var	Time of attitude set 1 observations (dec secs)
NVroll2	sI32	var	Aircraft roll (dec degs)
NVpitch2	sI32	var	Aircraft pitch (dec degs)
NVhead2	sI32	var	Aircraft heading (dec degs)
NVaqual2	UI32	var	attitude set 2 quality flags
NVsctcor	F64	1	Time correction from nav observation to scan observation
NVscnum	sI32	var	Scan number, see below
NVscsecs	sI32	var	Scan synchronisation time (GPS dec secs), see below
NVtime_sc	F64	1	Scale multiplier for time
NVasecs_sc	F64	1	Scale multiplier for attitude time
NVlat_sc	F64	1	Scale multiplier for latitude
NVlng_sc	F64	1	Scale multiplier for longitude
NVhgt_sc	F64	1	Scale multiplier for height
NVroll_sc	F64	1	Scale multiplier for roll
NVpitch_sc	F64	1	Scale multiplier for pitch
NVhead_sc	F64	1	Scale multiplier for head
NVscnum_sc	F64	1	Scale multiplier for scan number
NVscsecs_sc	F64	1	Scale multiplier for scan sync time

Notes:

1: Navigation vectors are stored as scaled integers (format sI32); file values are to be multiplied by the appropriate scale to obtain a double precision floating value.
2: Spheroid and datum codes are documented in Appendix A.
3: items NVscnum and NVscsecs link scanner scan-lines with the geolocation navigation. NVscsecs is the gps time of the scan number in the same index entry of NVscnum. Geographic location of a scan is then calculated by interpolation using gps time.

VGroup: SCAN COORDINATES

Contains post processed and interpolated navigation on a per scan basis. This is the Level 1B geolocation data on a one location point per scan basis. Common indexed entries in the CO vectors give the location data for the same index entry for the lline dimension in the image data SDS.

VGroup name: SCO
Vgroup title: Scan coordinates
Data item prefix: CO

Item name	type	maxv	description
COdesc	C8	64	Vgroup description: Navigation data interpolated to scan times
COprog1	C8	40	Vgroup 1st processing program
COprog2	C8	40	Vgroup 2nd processing program
COoffs	I32	1	Offset code for scanner in aircraft
COstime	I32	1	Time of site start (dec secs)
COetime	I32	1	Time of site end (dec secs)
COsscan	I32	1	Scan number of site start
COescan	I32	1	Scan number of site end
COscans	I32	1	Total scans with navigation
COscint	I32	1	Interval of scan number for scans with navigation
COtime	sI32	var	Time (GPS dec secs)
COutc	sI32	var	Time (UTC dec secs)
COlat	sI32	var	Latitude (dec degs)
COlng	sI32	var	Longitude (dec degs)
COhgt	sI32	var	Spheroid height (metres)
COalt	sI32	var	Altitude above local datum (metres)
COroll	sI32	var	Roll (dec degs)
COpitch	sI32	var	Pitch (dec degs)
COhead	sI32	var	Heading (dec degs)
COqual	UI32	var	Interpolation quality OR'd flag, 0= interp/extrap, 1= posn, 2= attitude
COtime_sc	F64	1	Scale multiplier for time
COlat_sc	F64	1	Scale multiplier for latitude
COlng_sc	F64	1	Scale multiplier for longitude
COhgt_sc	F64	1	Scale multiplier for height
COroll_sc	F64	1	Scale multiplier for roll
COpitch_sc	F64	1	Scale multiplier for pitch

COhead_sc	F64	1	Scale multiplier for heading

VGroup: MAPPING DETAILS

This Vgroup is present on Level 3 files only and contains mapping parameters used for final image correction in AZGCORR.

Vgroup name: MAP
Vgroup title: Mapping details
Data item prefix: MP

Item name	type	maxv	description
MPdesc	C8	64	Vgroup description: Mapping parameters for level 3
MPprog1	C8	40	Vgroup 1st processing program
MPsphc	I32	1	Spheroid code for map projection
MPdatm	I32	1	Datum shift code from navigation to mapping datum
MPproj	I32	1	Map projection code
MPlng0	F64	1	Longitude of origin
MPlat1	F64	1	Latitude of origin or 1st parallel
MPlat2	F64	1	2nd parallel
MPglat	F64	1	Latitude of grid origin
MPglng	F64	1	Longitude of grid origin
MPgx0	F64	1	Grid coordinate at grid origin
MPgy0	F64	1	Grid coordinate at grid origin
MPscf	F64	1	Project scale factor at projection origin
MPdshc	I32	1	Datum shift code, aquisition to mapping datums
MPdsVG	C8	16	Datum shift name
MPdsvec	F64	7	Datum shift vector for single point transformations
MPimx0	F64	1	Image origin grid x
MPimy0	F64	1	Image origin grid y
MPtiles	I32	1	number of tiles in image
MPracs	I32	1	?
MPcxy	F64	var	tile coordinates

VGroup: LEVEL 2

Contains details of user application, level 2, processing.

Vgroup name: LV2
Vgroup title: Level2
Data itemprefix: L2

Item name	type	maxv	description
L2desc	C8	64	Vgroup description: Level 2 user processed data
L2prog1	C8	40	Vgroup 1st processing program
L2prog2	C8	40	Vgroup 2nd processing program
L2para1	C8	128	User program parameter list1
L2para2	C8	128	User program parameter list2

VGroup: ATM

Contains ATM scanner recording parameters and recorded, calibrated or geometrically corrected image data stored as 16 bit integer to level 1b and either 16 bit integer or 32 bit floating for level 2 and level 3.
Level 1 data is inserted by ATM_1. Data recorded with the DEI320 has 12 channels and from the AZ16 11 channels.
Note this is for pre 2001 data, all ATM data from 2001 uses ATM2 below.

Vgroup name: ATM
Vgroup title: ATM
Data item prefix: AT

Item name	type	maxv	description
ATdesc	C8	64	Vgroup description: ATM scanner details, calibration and data
ATprog1	C8	40	Vgroup 1st processing program
ATprog2	C8	40	Vgroup 2nd processing program
ATprog3	C8	40	Vgroup 3rd processing program
ATprog4	C8	40	Vgroup 4th processing program
ATsbend	I32	1	Sbend correction applied in scanner flag 0= no, 1= yes (Note 1)
ATrgyro	I32	1	Roll gyro correction applied in scanner flag, 0= no, 1= yes (Note 1)
AThddt	C8	16	HDDT tape external label name (Note 1)
ATcct	C8	64	CCT tape external label name (Note 1)
ATtype	C8	8	Daedalus ATM type eg: 1268
ATid	C8	32	ATM ID

ATfov	F32	1	Field of view (dec degs)
ATpixfov	F32	1	Pixel field of view
ATpixrec	I32	1	Pixels per scan recorded
ATpixred	I32	1	Pixels per scan reduction method, 0= none, 1=average, 2= nearest
ATpixsav	I32	1	Pixels per scan saved
ATsscan	I32	1	Target start scan
ATescan	I32	1	Target end scan
ATchan	I32	1	Channels/bands recorded
ATbpix	I32	1	Bits per pixels recorded
ATgains	F32	var	Channel gains
ATwavu	F32	var	Channel upper wavelength limit
ATwavl	F32	var	Channel lower wavelength limit
ATscps	F32	1	Nominal scans per second recorded
ATbbtf	I32	1	Black body temperature saved type flag, 0= fixed for file, 1= table
ATbb1	F32	var	Black body 1 temperature
ATbb2	F32	var	Black body 2 temperature
ATbbscan	I32	var	scan at which temp applies for table option
ATcalfile	C8	32	calibration file name
ATcaltab	F32	100	calibration values table
ATradsc	F32	var	Channel radiance scaling multiplier
ATrunits	C8	32	Radiance units
ATimgmin	F32	var	Channels minimum values (excluding zero)
ATimgmax	F32	var	Channels maximum values (excluding overflows)
ATimgzer	I32	var	Channels no. of zero values
ATimgovr	I32	var	Channels no. of overflowed values
SCimtype	I32	1	Image type flag, 0= as source, 1= resampled
SCorder	I32	1	Pixel order flag, 0= l to r, 1= r to l in direction of lines increasing
SClndir	I32	1	Scan line direction flag, 0= flight direction, 1= north up
SCtiles	I32	1	Tiles in image, 0= not tiled single image, >0 = number of tiles
SCbands	I32	1	Bands in image
SCpixels	I32	1	Pixels in image
SClines	I32	1	Lines in image
SCpixfmt	I32	1	Pixel format flag, 0= 8bit unsigned, 1= 16bit unsigned
SCHDFfmt	I32	1	Pixel HDF number format flag, see HDF documentation for details
SCimover	F32	1	flag value indicating overflowed values, see general note 2
SCimunder	F32	1	flag value indicating underflowed or missing values, see gen note 2
SCpixbytes	I32	1	Bytes per pixel
SCposn	I32	1	Position data relation flag, 0= posns per scan, 1= posns per image
SCaxes	I32	1	Coordinate axes for position flag, 0= along flt dir, 1= N up
SCxypix	I32	1	relatio of coordinates to pixel flag, 0= centre, 1= BL
SCpixwid	F32	1	Pixel width - x or scan direction (metres)
SCpixhgt	F32	1	Pixel height - y or flight direction (metres)
SCviewty	I32	1	Image view type flag, see general note 4
SCvplane	I32	1	Image view (y) plane position (metres)
SCposimag	F64	var	Image position coordinates for SCposn=1, see general note 5
SCposscan	I32	1	Position info per scan content flag
SCsused	I32	var	scans used in level 3 image (field scan numbers)
SCbused	I32	var	bands used in level 3 image (level 1 band numbers)
SCpxyn	I32	1	No. of pixels per side of tile
SCpxy_sc	F64	1	Image xy scale multiplier
ATimgxy	I32	var	Image tiles coordinate list
ATdata	SDS	3 x var	Image data

ATM notes:

1: Items sbend, rgyro, hddt and cct are specific to the original ATM system

VGroup: ATM2

Version for AZ16 recorded data; note that some parameters have been changed from numerical flags to decriptive text to mak ethe Vgroup more readable. Contains ATM scanner recording parameters and recorded, calibrated or geometrically corrected image data stored as 16 bit integer to level 1b and either 16 bit integer or 32 bit floating for level 2 and level 3.
Level 1 data is inserted by ATM_1. Data recorded with the DEI320 has 12 channels and from the AZ16 11 channels.

Vgroup name: ATM2
Vgroup title: ATM2
Data item prefix: AT

Item name	type	maxv	description
ATdesc	C8	64	Vgroup description: ATM scanner details, calibration and data

ATprog1	C8	40	Vgroup 1st processing program
ATprog2	C8	40	Vgroup 2nd processing program
ATprog3	C8	40	Vgroup 3rd processing program
ATprog4	C8	40	Vgroup 4th processing program
ATsbend	I32	1	Sbend correction applied in scanner flag 0= no, 1= yes (Note 1)
ATrgyro	I32	1	Roll gyro correction applied in scanner flag, 0= no, 1= yes (Note 1)
ATrmedia	C8	64	recording media
ATtype	C8	8	Daedalus ATM type eg: 1268
ATid	C8	32	ATM ID
ATfov	F32	1	Field of view (dec degs)
ATfovp	F64	3	details of reduced filed of view, see below
ATpixfov	F32	1	Pixel field of view
ATpixrec	I32	1	Pixels per scan recorded
ATpixred	I32	1	Pixels per scan reduction method, 0= none, 1=average, 2= nearest
ATpixsav	I32	1	Pixels per scan saved
ATsscan	I32	1	Target start scan
ATescan	I32	1	Target end scan
ATchan	I32	1	Channels/bands recorded
ATbands	I32	var	Channels/bands saved to HDF file; see note 3, below.
ATbpix	I32	1	Bits per pixels recorded
ATwavu	F32	var	Channel upper wavelength limit
ATwavl	F32	var	Channel lower wavelength limit
ATscps	F32	1	Nominal scans per second recorded
ATbbtf	I32	1	Black body temperature saved type flag, 0= fixed for file, 1= table
ATbb1	F32	var	Black body 1 temperature
ATbb2	F32	var	Black body 2 temperature
ATbbscan	I32	var	scan at which temp applies for table option
ATsbb1	F32	var	Black body 1 set temperature
ATsbb2	F32	var	Black body 2 set temperature
ATvbb1	F32	var	Black body 1 viewed DN average
ATvbb2	F32	var	Black body 2 viewed DN average
ATsync	F32	var	??
ATcal	C8	16	indicates if data is calibrated
ATcalver	C8	16	version of calibration file
ATcalfmt	C8	16	format/layout of calibration file
ATcalfile	C8	32	calibration file name
ATcaltab	F32	var	calibration values table
ATgains	F32	var	gains ??
ATradsc	F32	var	Channel radiance scaling multiplier
ATrunits	C8	32	Radiance units
ATimgmin	F32	var	Channels minimum values (excluding zero)
ATimgmax	F32	var	Channels maximum values (excluding overflows)
ATimgzer	I32	var	Channels no. of zero values
ATimgovr	I32	var	Channels no. of overflowed values
SCimtype	C8	32	Image type: source or resampled 0 fill
SCorder	C8	32	Pixel in scan order: Left->Right or Right->Left direction of lines increasing
SClndir	C8	32	Scan line direction: flight direction or north up
SCtiles	C8	32	Tiles in image, not tiled = single image or number of tiles
SCbands	I32	1	Bands in image
SCpixels	I32	1	Pixels in image
SClines	I32	1	Lines in image
SCpixfmt	C8	1	Pixel format: 8bit unsigned, 16bit unsigned
SCHDFfmt	I32	1	Pixel HDF number format flag, see HDF documentation for details
SCimover	F32	1	flag value indicating overflowed values, see general note 2
SCimunder	F32	1	flag value indicating underflowed or missing values, see gen note 2
SCpixbytes	I32	1	Bytes per pixel
SCposn	C8	32	Position data relation:posns per scan, posns per image
SCaxes	C8	32	Coordinate axes for position: along flt dir, N up
SCxypix	C8	32	relatio of coordinates to pixel: centre, BL
SCpixwid	F32	1	Pixel width - x or scan direction (metres)
SCpixhgt	F32	1	Pixel height - y or flight direction (metres)
SCviewty	C8	32	Image view type, see general note 4
SCvplane	I32	1	Image view (y) plane position (metres)
SCposimag	F64	var	Image position coordinates for SCposn=1, see general note 5
SCposscan	I32	1	Position info per scan content flag
SCsused	I32	var	scans used in level 3 image (field scan numbers)
SCbused	I32	var	bands used in level 3 image (level 1 band numbers)
SCpxyn	I32	1	No. of pixels per side of tile
SCpxy_sc	F64	1	Image xy scale multiplier
ATimgxy	I32	var	Image tiles coordinate list
ATdata	SDS	3 x var	Image data

ATM notes:

1: Items sbend, rgyro, hddt and cct are specific to the original ATM system
2: ATfov and ATfovp: if ATfov = 0.0 then a reduced filed of view has been applied to the original; ATpixred is the reduced number of pixels, ATfovp[0] = this same number, ATfovp[1] = port field of view angle from nadir and ATfovp[2] = starboard field of view angle.
3: From Jan 2003, ATM level 1 files may contain less than the total number of bands recorded. The basic ATM recorded by the AZ16 data system acquires 11 bands 1-11; if all bands are saved then ATbands will contain 11 values from 1-11(or optionally ATbands will not be present) and SCbands will = 11. If it contains less then SCbands will be <11 and ATbands will have the list of saved bands; these will be numbered as for the original acquired bands AND will be in the user requested order NOT increasing band number order. There may be as few as 1 band for a thermal only flight. Bands not saved will not take space on the HDF file. **Note:** the VGroup items: ATwavu, ATwavl, ATgains, ATradsc, ATimgmin, ATimgmax, ATimgzer, ATimgovr will have the same dimension as ATbands and the contents will refer to the same bands as the numbers in ATbands.

VGroup: CASI

Contains CASI scanner recording parameters and recorded, calibrated or geometrically corrected image data stored as 16 bit integer to level 1b and either 16 bit integer or 32 bit floating for level 2 and level 3. Up to three sets of image data may occur: Image, SRC and ILS, see ITRES CASI documentation.

Contains
Vgroup name: CAS
Vgroup title: CASI
Data item prefix: CA

Item name	type	maxv	description
CAdesc	C8	64	Vgroup description: CASI scanner details and data
CAprog1	C8	40	Vgroup 1st processing program
CAprog2	C8	40	Vgroup 2nd processing program
CAprog3	C8	40	Vgroup 3rd porcessing program
CAprog4	C8	40	Vgroup 4th processing program
CAserial	I32	1	*CASI scanner serial number
CAswver	C8	32	*CASI scanner software version number
CAexa	C8	64	Exabyte tape external label name
CAfnum	I32	1	Field tape file number
CAconfig	C8	32	Scanner configuration file name
CAsday	I32	1	Target start day of year
CAstime	I32	1	Target start time (HHMMSS)
CAmode	I32	1	*CASI operating mode flag, 0= spatial, 1= spectral, 2= full frame
CAg	F64	4	*G coefficients
CAinteg	F32	1	*CCD integration period (msecs)
CAapert	F32	1	*CASI file header reported aperture
CAfapert	F32	1	Aperture appearing in majority of none dark frame headers
CAoaxis	F32	1	Pixel of CCD optical axis
CAfov	F32	1	Total field of view (dec degs)
CAfovport	F32	1	partial fov from port side to nadir
CAfovpix	I32	1	pixels visible in fov
CApsfov	F32	var	pixel view angle table from port, see general note: 6
CApside	I32	1	CCD port side flag
CAsscan	I32	1	Site start scan
CAescan	I32	1	Site end scan
CAlooks	I32	1	*Number of looks in spectral image
CAlooksp	I32	1	*Look spacing in spectral image
CAlookc	I32	1	*Centre look pixel in spectral image
CAsumdch	I32	1	*Number of channels per band summed in enhanced spectral
CAsrcpres	I32	1	SRC image present flag, 0= no, 1= yes
CAsrcbands	I32	1	SRC no. of bands
CAsrcchan	I32	1	band used for src
CAsrcpix	I32	1	SRC no. pixels
CAilspres	I32	1	ILS present flag, 0= no, 1= yes
CAilsbands	I32	1	ILS no. of bands
CAilspix	I32	1	ILS no. of pixels
CAbstart	I32	var	*band start of image data
CAbend	I32	var	*band end of image data
CAwavc	F32	var	*wavelength centre
CAwavh	F32	var	*wavelength half bandwidth
CAcalfile	C8	32	Calibration file name
CAradsc	F32	1	Radiance scaling multiplier
CArunits	C8	32	Radiance units
CAiunits	C8	32	ILS irradiance units
CAimgmin	F32	var	Image bands minimum, excluding zeros
CAimgmax	F32	var	Image bands maximum, excluding overflows
Caimgzer	I32	var	Image bands zeros
CAimgovr	I32	var	Image bands overflows

CAsrcmin	F32	var	SRC band minimum, excluding zeros
CAsrcmax	F32	var	SRC band maximum, excluding overflows
CAsrczer	I32	var	SRC band zeros
CAsrcovr	I32	var	SRC band overflows
CAilsmin	F32	var	ILS bands minimum, excluding zeros
CAilsmax	F32	var	IILS bands maximum, excluding overflows
CAilszer	I32	var	ILS bands zeros
CAilsovr	I32	var	ILS bands overflows
SCimtype	I32	1	Image type flag, 0= as source, 1= resampled
SCorder	I32	1	Pixel order flag, 0= l to r, 1= r to l in direction of lines increasing
SClndir	I32	1	Scan line direction flag, 0= flight direction, 1= north up
SCtiles	I32	1	Tiles in image, 0= not tiled single image, >0 = number of tiles
SCbands	I32	1	Bands in image
SCpixels	I32	1	Pixels in image
SClines	I32	1	Lines in image
SCpixfmt	I32	1	Pixel format flag, 0= 8bit unsigned, 1= 16bit unsigned
SCHDFfmt	I32	1	Pixel HDF number format flag, see HDF documentation for details
SCimover	F32	1	flag value indicating overflowed values, see general note 2
SCimunder	F32	1	flag value indicating underflowed or missing values, see gen note 2
SCpixbytes	I32	1	Bytes per pixel
SCposn	I32	1	Position data relation flag, 0= posns per scan, 1= posns per image
SCaxes	I32	1	Coordinate axes for position flag, 0= along flt dir, 1= N up
SCxypix	I32	1	relation of coordinates to pixel flag, 0= centre, 1= BL
SCpixwid	F32	1	Pixel width - x or scan direction (metres)
SCpixhgt	F32	1	Pixel height - y or flight direction (metres)
SCviewty	I32	1	Image view type flag, see general note 4
SCvplane	I32	1	Image view (y) plane position (metres)
SCposimag	F64	var	Image position coordinates for SCposn=1, see general note 5
SRCposimag	F64	var	SRC image position if different from Spectral or Enhance Spectral data image
SCposscan	I32	1	Position info per scan content flag
SCsused	I32	var	scans used in level 3 image (field scan numbers)
SCbused	I32	var	bands used in level 3 image (level 1 band numbers)
SCpxyn	I32	1	No. of pixels per side of tile
SCpxy_sc	F64	1	Image xy scale multiplier
CAimgxy	sI32	var	Image xy coordinates
CAsrcxy	sI32	var	SRC xy coordinates
CAilsxy	sI32	var	ILS xy coordinates
CAimage	SDS	3 x var	Image data, spectral or spatial bands
CAsrc	SDS	3 x var	SRC data, scene recovery for spectral mode
CAils	SDS	3 x var	ILS data

CASI notes

1: Descriptions starting with * indicate values transferred without alteration from the CASI data file. Full details can be found in CASI documentation.

General Notes

1: Data types:

C8	CHAR8	8 bit characters, used for text strings which are zero terminated
I32	INT32	32 bit signed integers
sI32	INT32	32 bit integers containing scaled floating point values
UI32	UINT32	32 bit unsigned integer
F32	FLOAT32	32 bit floating point
F64	FLOAT64	64 bit floating point
SDS	see below	format indicated by SCHDFfmt, may be UINT16 or FLOAT32

Item dimensions marked as variable (var) or SDS may be of any length.
Variable and SDS items only appear in VGroups if they have 1 or more values.

2: Image items

On all AZSPS file levels, image items are stored as HDF SDS (Scientific Data Sets). The layout and dimensions have been chosen so that the "line" dimension is variable. Data is stored in the SDS items with the following convention:

Level 1 pixel order is, as recorded, by the instrument, eg for the ATM pixel 0 is on the port side of the flight path. Line order is as recorded in flight direction. Band order is from 1 to however many bands.

Level 3 If the image is created as a "north up" one then it is ordered for quadrant 1, ie pixels increase as x increases, left to right; lines increase as y increases from south to north of image. If the "head up" image creation was selected then the images axes are, x across the flight direction, increasing left to right with pixel 0 on the left; y is in flight direction, increasing bottom to top of image, line 0 is at the bottom.

Level 3 images outside the flight line area are zero filled.

Note that **azexhdf** has options to create output files ordered to suit other conventions.

Image items are either direct instrument recorded data or values derived from these. Allowance is made for values overflowed, underflowed or missing. The following strategy has been adopted and must be followed in level 2 processing to remain compatible with level 3 programs.

a) UINT16 image items have two special values:
0xffff (65536) indicates an overflowed value
zero indicates underflowed or missing data
b) FLOAT32 image items have two similar special values; to allow for flexibility for level 2 processing these values are stored in ATM and CAS Vgroup items, SCimover and SCimunder. The following rule must be adhered to to avoid image data loss: valid image items must be between SCimover and SCimunder; images values >= SCimover and <= SCimunder will be omitted from level 3 calculations.

Note that these items are valid for UINT16 and FLOAT32 image data.

Default values are: UINT16 SCimover 65536.0 SCimunder 0.0
Default values are: FLOAT32 SCimover 1.0e^30 SCimunder -1.0e^30

3: Tiled images

Image tiling is indicated by SCtiles > 0. Image is tiled into side by side squares (by no. of pixels). Image data for tiles are stored in the image data items ATdata, CAimage (spatial mode), CAsrc. Note that CAimage (spectral mode) and CAils are not tiled and always stored in one piece. The key to the position of tiles is stored in the appropriate VG***xy item after scaling. Image data for squares may be in any order from the total image area; the key may be ordered for best access or other reasons.
a) SCpxyn, SCpxy_sc, ATimgxy, CAimgxy, CAsrcxy and CAilsxy are only used if the image is tiled.
b) In none tiled files, image items are stored as bands, lines and pixels. Typically Level 1 and 2 data is none tiled and Level 3 may be either.

4: Derived image views

Images resulting from level 3 processing are projected to a surface different from the aquisition surface, the selected surface is indicated by the SCviewty flag with values:
0= as source = image is as original and not resampled
1= mean sea level of local datum
2= to a plane parallel with the mapping spheroid (fixed GPS flight height)
3= to observed flight height + corrrection
4= digital elevation model (DEM) in local datum
5= DEM + Geoid/Spheroid correction (navigation to mapping spheroids)

5: Image Coordinates

The position of a resampled and corrected image is defined by a set of corrdinate values and increments:
With origin at pix[0], line[0] and using map projection grid coordinates; SCposimag (and SRCposimag) values are:
[0] = pixels, [1] = lines, [2] = x origin BL pixel, [3]= y origin BL pixel, [4]= xinc per pixel, [5]= yinc per pixel, [6]= xinc per line, [7]= yinc per line

Using this vector the coordinates any any pixel: [pix, line] (zero relative) is given by;

x = posimag[2] + pix * posimag[4] + line + posimag[6]
y = posimag[3] + pix * posimag[5] + line + posimag[7]